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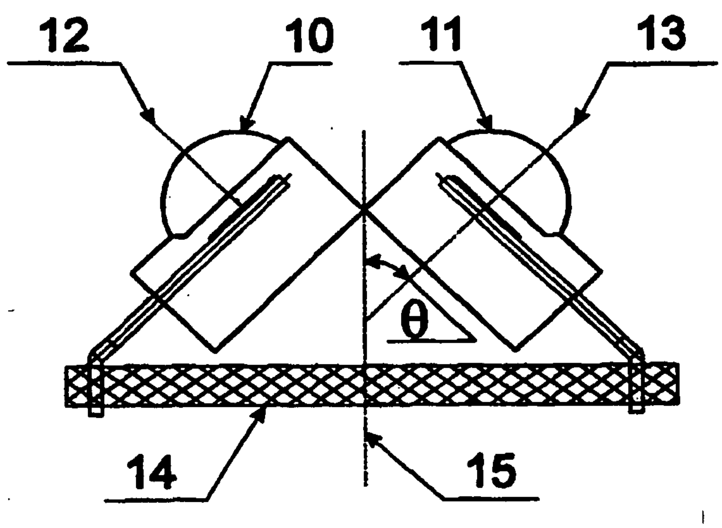
(54) Title: INFRARED RECEIVER HAVING IMPROVED SPATIAL COVERAGE



(57) Abstract

An infrared receiver having improved spatial coverage, comprising at least two mutually angularly spaced apart infrared diodes (10, 11) each having a respective axis of maximum sensitivity (12, 13) inclined at an acute angle (θ) to a common axis (15). The infrared diodes may be mounted on a respective surface of a polyhedral housing and may be discrete components or encapsulated in a common encapsulation. A method for increasing a relative sensitivity of an infrared receiver to a beam directed at an oblique angle to a reference direction, comprises sacrificing the sensitivity to a direct strike for the sake of the sensitivity to an oblique strike.

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Infrared receiver having improved spatial coverage

FIELD OF THE INVENTION

This invention relates to infrared detectors and in particular to infrared receivers having improved spatial coverage.

BACKGROUND OF THE INVENTION

Infrared receivers typically include an infrared photodiode detector. Such infrared detectors are maximally sensitive when the direction of propagation of the infrared beam is along an axis of the infrared detector. When this is not the case and the direction of propagation of the infrared beam is at an oblique angle to the axis of the infrared detector, the sensitivity falls off: sometimes acutely.

Figures 1 and 2 are graphs showing the respective relative sensitivities of two infrared photodiode detectors provided by the Telefunken Company under the Catalogue Numbers BPV22NF and BPV10NF. In these graphs, the straight lines represent the angular direction of the infrared beam relative to the "normal", i.e. perpendicular to the plane of the detector element, e.g. silicon. The curved lines represent loci of equal sensitivity. From Figure 1, it is seen that for the BPV22NF which is considered a wide angle photodiode, when the propagation axis is at 10° to the normal, the drop in relative sensitivity is negligible. When the propagation axis increases to 40° to the normal, the relative sensitivity is equal to 0.8. With a propagation axis of 60°, the relative sensitivity falls to 0.5. When the propagation axis increases to 80° to the normal, the relative sensitivity falls to approximately 0.15.

On the other hand, as seen in Figure 2, the BPV10NF is much more uni-directional. When the propagation axis is at 10° to the normal, the relative sensitivity already falls to 0.9. When the propagation axis is as little as 20° to the normal, the relative sensitivity falls to 0.5; and when the propagation axis is at 50° to the normal, the relative sensitivity falls drastically to 0.1.

Many appliances are controlled remotely using infrared detectors. The only way in which it is possible to increase the relative intensity of the beam reaching the detector is to ensure that the infrared beam is directed along the axis of the infrared detector. This is not always feasible, there being many occasions when there is no choice but to control an appliance from an angle which is oblique to the normal axis of the infrared detector.

Currently, the manner in which such a *desideratum* is achieved may be summarized as follows. First, as already suggested, it is possible to use infrared diodes having improved spatial coverage characteristics. It is also known to employ optical techniques such as lenses for increasing the field of detection of the detector. It is also known to employ multiple infrared detectors so as effectively to increase the sensitivity of the receiver. In this context, it will be understood that the effective sensitivity of an infrared detector is a function of the area of silicon or other sensitive material in the infrared diode. Thus, by increasing the area of silicon, the effective sensitivity of the detector can also be increased. By employing multiple detectors, therefore, it is possible to increase the effective area of silicon and thus the effective sensitivity of the detector.

Finally, mention must be made of various electronic means for increasing the detector signal and thus allowing registration of a detected signal which would otherwise be of too low intensity.

All of these techniques suffer from various drawbacks: some commercial and some conceptual. It will clearly be understood that using optical or electronic techniques requires yet additional design and assembly and thus increases the cost of the resulting infrared receiver. The use of multiple

infrared detectors also increases the cost but not to the same extent since infrared detectors are themselves mass produced and, consequently, one of the least expensive components in the receiver.

The drawback of using multiple infrared photodiode detectors in the manner in which they have so far been contemplated is more conceptual than commercial. As explained above, the conventional reasoning behind the use of multiple infrared photodiodes has been based on the fact that by increasing the effective area of silicon, the overall sensitivity of the detector is increased. This is true, but the characteristics of the receiver are still exactly the same characteristics as the individual, component infrared photodiodes as shown, for example, in Figures 1 and 2. As a result, even with such detectors, although the overall sensitivity is admittedly increased, the relative spatial coverage is in no way altered. Specifically, if several BPV10NF infrared diodes are employed, then at the propagation axis equal to 30° to the normal, the relative sensitivity of the detector will still have fallen to 0.2.

This fall off in angular sensitivity militates against the common use of infrared transmitters (such as remote controls) having a fixed intensity, because as will be appreciated as the transmitter is held at an oblique angle to the detector, so too does the distance from the control to the detector increase. In order to compensate for this increase in distance, it would clearly be desirable to increase the sensitivity of the receiver so that, in fact, the receiver has an increased sensitivity for an oblique beam which has to travel a greater distance than for a "normal" beam wherein the propagation distance is minimal.

None of the prior art approaches to increasing the relative sensitivity of an infrared detector addresses this particular requirement.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide an infrared receiver having improved spatial coverage. It is a particular object of the invention to provide such a receiver wherein the sensitivity at an oblique angle to the "normal" is greater than that for a "normal" beam.

To this end, there is provided an infrared receiver having improved spatial coverage, comprising:

at least two mutually angularly spaced apart infrared photodiodes each having a respective axis of maximum sensitivity inclined at an acute angle to a common axis.

Thus, in the invention, at least two infrared detectors are employed each inclined at an acute angle to a common axis of the receiver. Consequently, a beam directed towards the receiver along the common axis thereof, will strike each of the infrared diodes at an oblique angle to its respective direction of maximum sensitivity. As a result, the signal intensity produced by each diode will be decreased relative to the maximum sensitivity of the diode. On the other hand, a beam directed at an oblique angle to the common axis of the receiver, will be more likely to strike one of the infrared detectors along its axis of maximum sensitivity: thereby producing a relatively higher output notwithstanding the fact that such an oblique beam has actually travelled through a larger propagation distance.

Such receiver may be mounted on a ceiling for relaying infrared signals from one floor-mounted device to another. Such ceiling-mounted receivers are particularly useful in infrared networks and the like since they are unobtrusive and well clear of furniture and other obstacles which might intercept the infrared beam and prevent its detection by the receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how the same may be carried out in practice, some preferred embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Figs. 1 and 2 are spatial sensitivity characteristics of typical known infrared detectors;

Fig. 3 shows schematically a pair of infrared detectors connected in accordance with one embodiment of the invention;

Fig. 4 shows schematically a pair of infrared detectors connected in accordance with a second embodiment of the invention; and

Fig. 5 shows pictorially an application of the invention to a ceiling mounted detector.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 3 shows schematically a detail of an infrared receiver comprising a pair of discrete infrared photodiodes 10 and 11 each having respective axes of maximum sensitivity 12 and 13. The two photodiodes 10 and 11 are mounted on a common printed circuit board (PCB) 14 so that their respective axes of maximum sensitivity 12 and 13 are inclined at an acute angle θ to a "common" axis 15 of the receiver. Although, typically, a symmetrical arrangement is employed such that each of the photodiodes 10 and 11 is orientated at the same angle θ to the common axis 15 of the receiver, this is not a requirement. Thus, improved spatial coverage will equally well be achieved even if each of the component diodes is orientated at a different angle to the common axis of the receiver.

The photodiodes 10 and 11 are discrete components that are connected in parallel by means of conductive leads which are soldered to the PCB 14. Two external connections (not shown) allow the PCB 14 to be connected to the

infrared receiver of which the photodiodes 10 and 11 are the active components.

Fig. 4 shows schematically an alternative embodiment of a detector depicted generally as 20 and having a pair of infrared sensitive planes 21 and 22, such as silicon, which are encapsulated in a common encapsulation for physical miniaturization and cost reduction. In this case, each silicon plane may have two conductive leads which allow for the two infrared sensitive planes 21 and 22 to be connected in parallel. However, it may be convenient to reduce the number of leads which thus emerge from the detector and to this end it is frequently desirable to connect at least some of the leads internally so the fewer leads require external interconnection.

Although, in Figs. 3 and 4, only a pair of infrared photodiodes is shown, in practice, the photodiodes can be mounted on corresponding faces of a polyhedral structure such as, for example, a pyramid so as to provide effectively 360° coverage. Here also, when encapsulated silicon components are employed, commonly connected leads from the component infrared sensitive planes are preferably connected internally so as to reduce the number of conductors projecting from the device. By increasing the number of component photodiodes, the sensitivity of the receiver even when the beam is directed along the common axis thereof is also enhanced since each of the component photodiodes will detect a fraction of the incoming beam, albeit at reduced sensitivity. At the same time, the use of multiple photodiodes increases the probability that an oblique beam will strike one of the photodiodes substantially close to its axis of maximum sensitivity.

Referring to Fig. 5 there is shown an application of the invention to a detector 25 ceiling-mounted centrally in a room 26 for receiving a control signal from a hand-held transmitter (not shown) held at waist height by a person standing in a corner of the room. If the height of the room is 2.6 m, then the approximate height of the transmitter is 1.6 m allowing for the fact that the

person's waist is approximately at a height of 1 m. The relevant data (all distances in meters) are as shown in the following table:

A	B	C	H	α	R
10	10	14.14	2.6	69.8°	7.53
10	10	14.14	1.6	77.2°	7.25

It is thus to be noted that the effective angle α of propagation between the infrared beam and the detector 25 is 77.2° to the vertical. At this angle, a single BPV10NF detector mounted normally so as to point directly downwards would have negligible relative sensitivity; whilst even for the wide angle BPV22NF the relative sensitivity falls drastically to approximately 0.15.

However, by employing multiple photodiode detectors in the configuration according to the invention, the relative off-axis propagation of the infrared beam to at least one of the component infrared detectors may be minimized so that the response from that detector is substantially unimpaired. On the other hand, were the beam to be directed upwards to such a multiple photodiode detector, the beam would then strike each of the component photodiode detectors off axis, thereby reducing their response. It is thus seen that the invention sacrifices the sensitivity for a direct strike for the sake of the sensitivity for an indirect strike.

It is also to be noted that the invention has general application for hand-held transceivers, such as badges, having receive capability. Instead of employing only a single IR photodiode, there may be provided an array according to the invention in order to improve the spatial coverage thereof.

CLAIMS:

1. An infrared receiver having improved spatial coverage, comprising:

at least two mutually angularly spaced apart infrared diodes (10, 11) each having a respective axis of maximum sensitivity (12, 13) inclined at an acute angle (θ) to a common axis (15).

2. The infrared receiver according to Claim 1, wherein each one of the infrared diodes is mounted on a respective surface of a polyhedral housing (20).

3. The infrared receiver according to Claim 1 or 2, wherein each one of the infrared diodes is a discrete component.

4. The infrared receiver according to Claim 1 or 2, wherein the infrared diodes are encapsulated in a common encapsulation.

5. A hand-held transceiver comprising the infrared receiver according to any one of the preceding claims.

6. A method for increasing a relative sensitivity of an infrared receiver to a beam directed at an oblique angle to a reference direction, comprising sacrificing the sensitivity to a direct strike for the sake of the sensitivity to an oblique strike.

7. A method for receiving an infrared beam transmitted at an oblique angle to a vertical direction, the method comprising the step of mounting the infrared receiver according to any one of Claims 1 to 4 on a ceiling with said common axis disposed along said vertical direction.

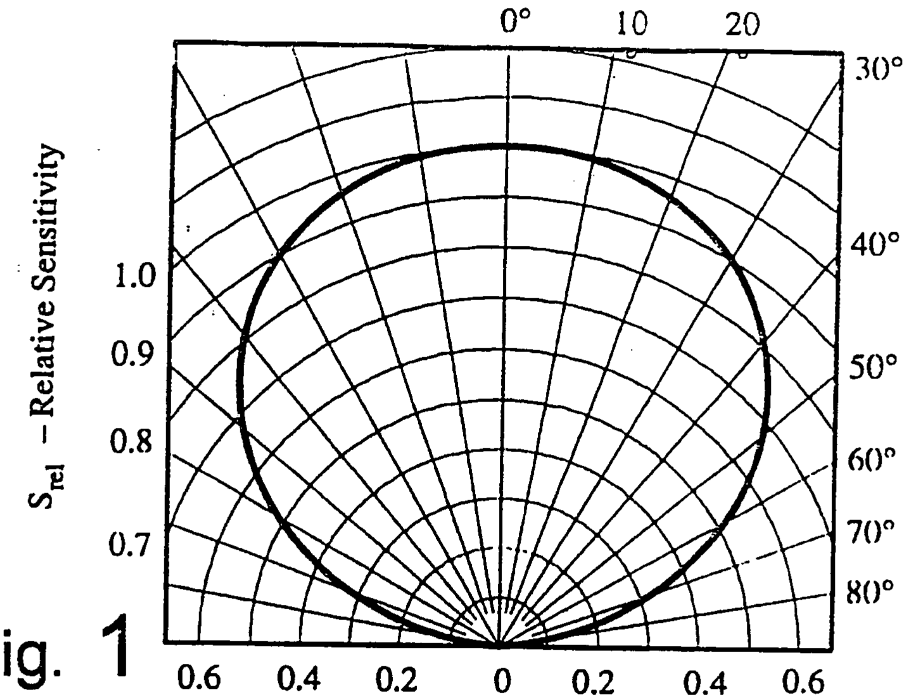
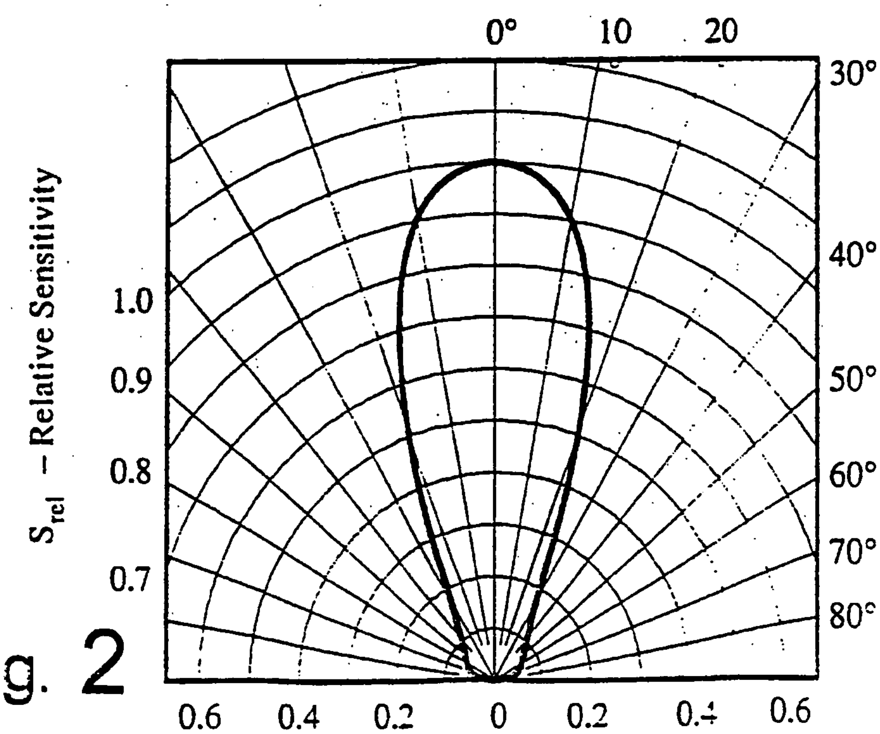

0°
10
20
30°
40°
50°
60°
70°
80°
S_{rel} – Relative Sensitivity
1.0
0.9
0.8
0.7
0.6
0.4
0.2
0
0.2
0.4
0.6

Fig. 1


0°
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S_{rel} – Relative Sensitivity
1.0
0.9
0.8
0.7
0.6
0.4
0.2
0
0.2
0.4
0.6

Fig. 2

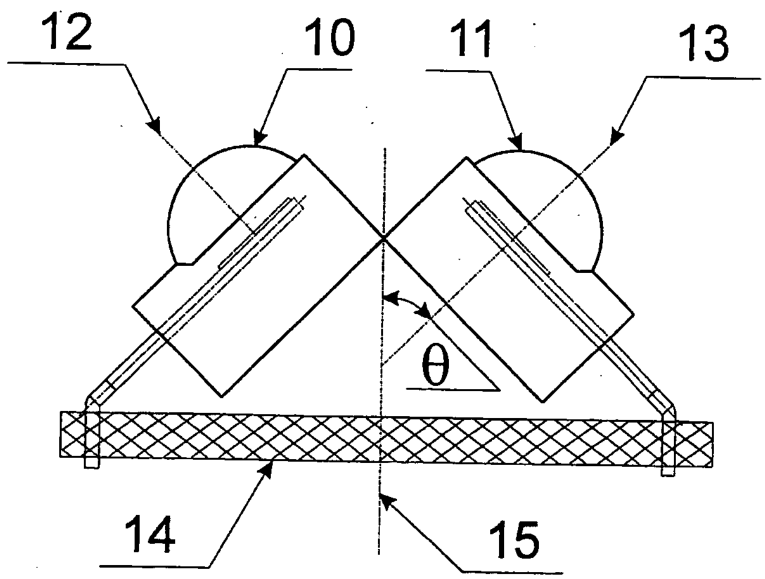

Fig. 3

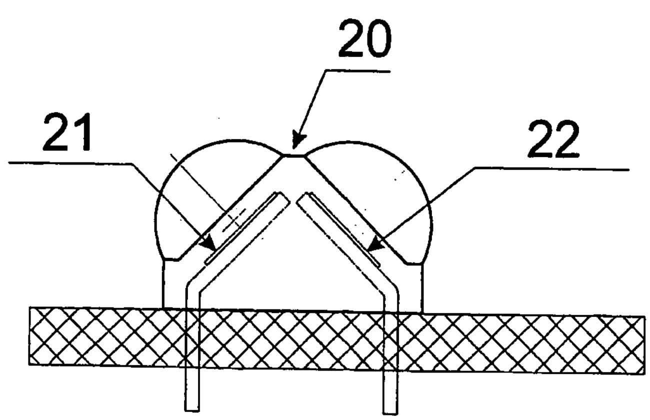

Fig. 4

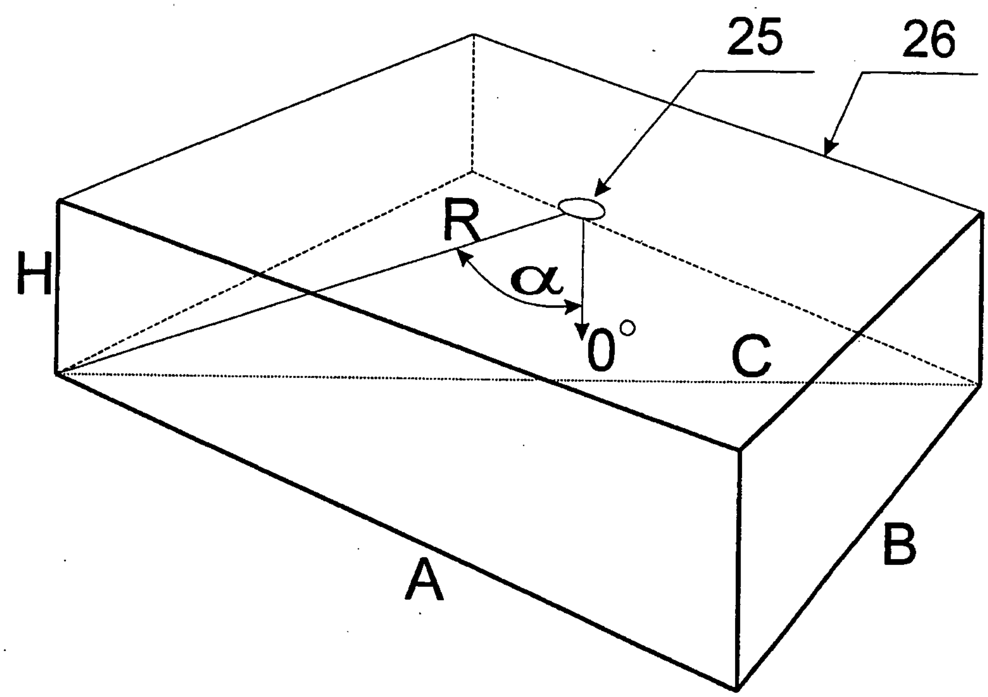

Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 98/00537

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01L31/0203

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01L

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Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 012, no. 228 (E-627), 28 June 1988 & JP 63 020875 A (MATSUSHITA ELECTRONICS CORP), 28 January 1988 see abstract	1
A		2-7
A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 136 (E-320), 12 June 1985 & JP 60 018975 A (FUJITSU KK), 31 January 1985 see abstract	1
A	EP 0 645 824 A (NIPPON ELECTRIC CO) 29 March 1995 see figures 4-7	1,4

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 105 239 A (UCHINO TSUGUO ET AL) 14 April 1992 see figure 14	1,2

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Information on patent family members

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